The ATLAS electromagnetic calorimeter : construction, commissioning and selected test beam results

G. Sauvage

LAPP-EXP 2004-12
December 2004

The ATLAS electromagnetic calorimeter : construction, commissioning and selected test beam results

G. Sauvage

LAPP-IN2P3-CNRS
9 chemin de Bellevue - BP. 110
F-74941 Annecy-le-Vieux Cedex

Presented at the 9th Topical Seminar on Innovative Particle and Radiation Detectors, Siena, Italy, 23-26 May 2004

The ATLAS electromagnetic calorimeter: construction, commissioning and selected test beam results

G. Sauvage[a] , on behalf of the ATLAS collaboration

[a]Laboratoire de Physique des Particules d'Annecy-le-Vieux (LAPP),
B.P. 110, 74971 Annecy-le-Vieux Cedex, France

The construction of the ATLAS electromagnetic calorimeter is finished. The barrel calorimeter is undergoing a cooling test. One end cap is already inserted in its cryostat and awaiting its cooling test and the second one will be inserted soon. The key parameters and qualification tests are summarized and the most important test beam results are given.

1. INTRODUCTION

The electromagnetic calorimeter of the ATLAS experiment at CERN's future proton-proton collider, the LHC, is a lead-liquid argon sampling calorimeter with accordion shaped absorbers and electrodes. Calorimetry will be a crucial tool in the understanding of proton-proton collisions at LHC, since many physics processes whose discovery or detailed study is expected, like for example $H \to \gamma\gamma$, $H \to 4e$, $H \to WW$ will manifest themselves through final states with electrons or photons. Precise measurement of the properties of the electrons and photons is of utmost importance, and dynamic range, resolution and uniformity are the main parameters that have to be optimized. From physics simulations[1], it has been determined that the electromagnetic calorimeter has to meet the following requirements:

- For a Higgs boson decaying to two photons or to four electrons, in the mass range going from 90 to $180\,\mathrm{GeV/c^2}$, ATLAS should be able to measure the Higgs mass with 1% precision using the calorimeter system only. This translates into the requirements of a sampling term of $10\%/\sqrt{E}$ or better, associated with a constant term better than 1%.
- The calorimeter must be able to separate the two photons from a π^0 decay.
- The dynamic range has to cover 30 MeV up to 1 TeV, i.e. from the typical noise level in one single cell up to the single cell energy deposition expected in the case of the decay of a Z' or W' with a mass up to $6\,\mathrm{TeV/c^2}$.

Liquid argon calorimetry has been chosen for ATLAS because of its intrinsic linear behavior, stability of the response in time and radiation tolerance. The accordion geometry has been chosen because it allows very good hermeticity. In addition, the accordion geometry minimizes inductances in the signal paths, allowing the use of the fast shaping needed to cope with the 25 ns interval between bunch collisions at LHC.

In the next section the design of the calorimeters and the present status are given. The main results obtained for series modules exposed in a beam test are summarized in section 3.

2. DETECTOR DESIGN AND DETECTOR STATUS

2.1. Detector design

To meet the above requirements, ATLAS has chosen to build a lead/liquid argon electromagnetic calorimeter, comprising a barrel and two end caps. The barrel, covering the $0 < |\eta| < 1.475$ range, shares its cryostat with the superconducting solenoid, the calorimeter being behind the solenoid. Both end caps, covering the $1.4 < |\eta| < 3.2$ range, are in the same cryostats as the hadronic and forward liquid argon calorimeters.

To evaluate the amount of energy lost in front of the calorimeters (the material amounts to about $1.5\,X_0$), both end caps and barrel are complemented with presampler detectors, covering the $0 < |\eta| < 1.8$ range. Basically these presamplers are thin layers of argon equipped with readout electrodes but no absorber.

A general view of the mechanical structure of the electromagnetic barrel calorimeter is given in Fig. 1. The accordion shape of the absorbers and electrodes has been chosen because it allows to build the detector without any cracks in ϕ, with the HV supply cables and signal cables running on the front and back face of the detector. These cables are connected to the feedthroughs situated at both cryostat extremities. The front end boards are located in crates sitting just above these feedthroughs. To ease the construction, each half barrel is divided in 16 modules.

The electromagnetic end cap calorimeter has a mechanical structure similar to the barrel calorimeter, but with absorbers arranged like the spokes of a bicycle wheel. However, whereas the barrel calorimeter uses only one type of absorbers and has a constant gap thickness, the end cap uses two types of absorbers, one for the outer wheel ($1.4 < |\eta| < 2.5$) and one for the inner wheel ($2.5 < |\eta| < 3.2$), with varying gap thicknesses requiring different HV values as function of η to maintain a constant response with η.

The barrel calorimeter η range is covered by two electrodes. The transition between the two electrodes correspond also to a change in lead thickness, needed to prevent the sampling ratio from increasing too much with η. The end-cap has also 2 different electrodes, one covering the inner wheel and the other one the outer wheel. Similarly to the barrel, the transition between the two electrodes corresponding also to a change in the lead thickness of the absorbers. Each end cap is subdivided in 8 modules. The electromagnetic calorimeters are finely segmented. For example, in the barrel region, the granularity is $\Delta\eta \times \Delta\phi = 0.003 \times 0.1$ for the first sampling section, optimizing the ability to separate photons from π^0 energy deposits, $\Delta\eta \times \Delta\phi = 0.025 \times 0.025$ for the middle sampling mainly devoted to the energy measurement and $\Delta\eta \times \Delta\phi = 0.050 \times 0.025$ for the third sampling. More details on the electromagnetic calorimeters can be found in [2].

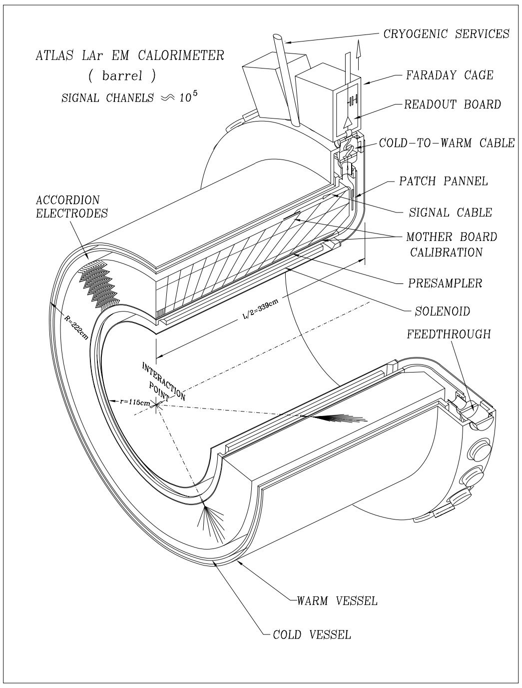

Figure 1. General view of one half of the electromagnetic barrel calorimeter inside its cryostat.

2.2. Detector status at mid 2004

The construction of the barrel calorimeter has taken about two years and is now finished. Both half barrels have been inserted in the barrel cryostat, as shown in Fig. 2. The installation of the solenoid is also finished and the cryostat has been closed. A cooling test with liquid argon is underway. The barrel calorimeter should be ready for installation in the ATLAS pit by september 2004.

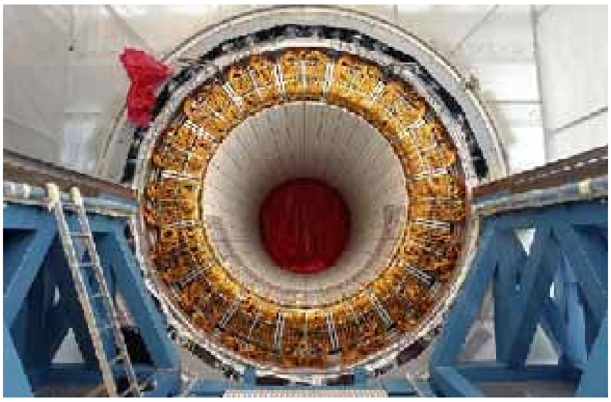

Figure 2. First half barrel inserted inside the ATLAS cryostat

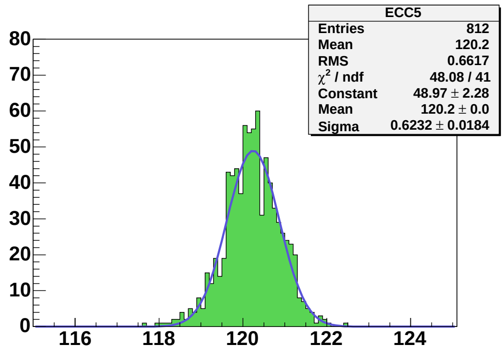

Figure 3. Uniformity in ECC5 end cap module: an uniformity of 0.52% has been achieved on a total of 812 cells.

The two end caps calorimeters are also built. The first end cap is already inserted and the second one is ready to be inserted. The first end cap cryostat containing its electromagnetic, hadronic and forward calorimeters is awaiting the cooling test.

2.3. Quality controls

To ensure that the calorimeters will meet the requirements defined above, numerous quality controls have been performed during the whole construction phase. For example:

- the variation of the lead thickness has been mimimized by controlling the lead thickness during the rolling and by pairing the absorbers in the stacking. This has led to a contribution to the constant term less than 0.18% for the barrel. The absorber thickness, inducing gap variation, leads to a contribution of less than 0.1% to the constant term.

- The two sides of each electrode sector (one sector covers typically $\Delta\eta \times \Delta\phi = 0.2 \times 0.2$) are powered independently. In case of HV problems, encountered during the cold test of each module or during the assembly of the calorimeter, only one side of the concerned sector is disconnected. After insertion of the barrel and of the first end cap in their respective cryostats, the numbers of electrode sectors having a problem is at the level of 0.15%.

- All signal channels have been pulsed via the calibration lines and the total number of dead channels after insertion of the barrel and of the first end cap is less than 0.15%.

3. SELECTED BEAM TEST RESULTS

4 barrel and 3 end cap modules have been exposed to an electron beam at CERN during the production. Preliminary results on the uniformity, the energy resolution and the ability to detect muons are presented here. Final results will be published soon [3].

Fig. 3 and Fig. 4 show the results obtained for a significative number of cells of an end cap and a barrel module. The aim to get an uniformity better than 0.5% in a $\Delta\eta \times \Delta\phi = 0.2 \times 0.2$ region (smaller than the region shown in the figures) is achieved.

Several energy scans have been performed. Fig. 5 shows an example of resolution obtained for a barrel module. A sampling term of less than 10% has been obtained, as expected.

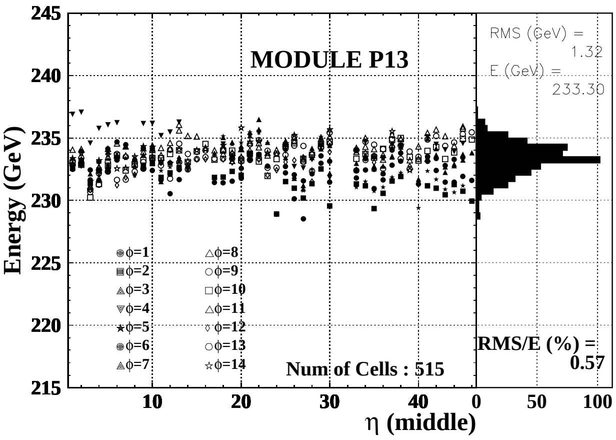

Figure 4. Uniformity in P13 barrel module: an uniformity of 0.57% has been achieved on a total of 515 cells.

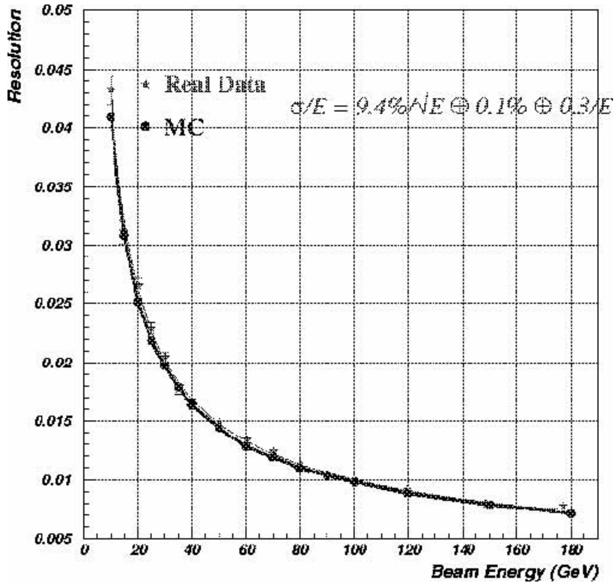

Figure 5. Example of energy resolution for a barrel module with a sampling term of 9.4%.

Muons accompanying the electron beam have been used to measure the signal for non interacting particles. A signal to noise ratio between 7 and 12 is observed for middle cells in the barrel, and summing up the middle and back cells in the end cap the ratio signal to noise is 7. This gives the possibility to see cosmic muons in the ATLAS pit in 2006 before the LHC turn on in 2007.

4. CONCLUSION

The construction of the ATLAS electromagnetic calorimeter, including the barrel and the two end caps is now finished. The electromagnetic barrel undergoes a cold test at liquid argon before its installation in the ATLAS detector in LHC. The cold tests of the end caps will follow the barrel cold test. The results of the calibration of the modules exposed to an electron beam meet the requirements imposed by the physics at LHC.

REFERENCES

1. ATLAS Collaboration, *ATLAS : Detector and Physics Performance ; Technical Design Report, Volume I and II*, CERN LHCC-99-014 and CERN LHCC-99-015.
2. ATLAS Collaboration, *Calorimeter Performance ; Technical Design Report*, CERN LHCC-96-040.
   ATLAS Collaboration, *Liquid Argon Calorimeter ; Technical Design Report*, CERN LHCC-96-041.
   ATLAS Collaboration, *Construction, assembly and first tests of the ATLAS electromagnetic barrel calorimeter*, to be published.
   ATLAS Collaboration, *Construction, assembly and first tests of the ATLAS electromagnetic end cap calorimeter end*, to be published.
3. ATLAS collaboration, *test beam results* to be published.